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Lonergan,R.P.; Hall,L.B.

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A METHOD OF PREDICTING THE EFFECT OF NOZZLE EROSION FROM WATER-WETTABLE INSECTICIDES ON THE DISCHARGE RATES OF NOZZLES

RICHARD P. LONERGAN*

LAWRENCE B. HALL**

Technical Development Laboratories, Communicable Disease Center, Bureau of State Services, Public Health Service, US Department of Health, Education, and Welfare, Savannah, Ga., USA

SYNOPSIS

Nozzle erosion can result in a considerable economic loss to a malaria control programme owing to overapplication of insecticides. The factors responsible for increased discharge rate due to nozzle erosion may vary considerably. Consequently, criteria determined for one or two sets of erosion conditions cannot be generally applied. A method has been developed which permits any individual programme to evaluate spray nozzles under the applicable nozzle erosion conditions. This method has the additional advantage of requiring only two discharge rate determinations instead of a series.

The erosion of nozzle orifices by suspensions of water-wettable insecticide powders has been of considerable interest to malaria control workers in many countries. Erosion by the insecticide passing through the orifice results in orifice enlargement. Field and laboratory investigations have demonstrated that nozzle erosion can result in a considerable economic loss to a programme, owing to overapplication of insecticides.

The factors responsible for this increase in discharge rate may vary considerably. Consequently, criteria determined for one or two sets of nozzle erosion conditions cannot be generally applied. The method presented below permits any individual programme to evaluate spray nozzles under the applicable nozzle erosion conditions. This method has the additional advantage of requiring only two discharge rate determinations instead of a series.

* Sanitary Engineer, Equipment Development Section
** Chief, Equipment Development Section

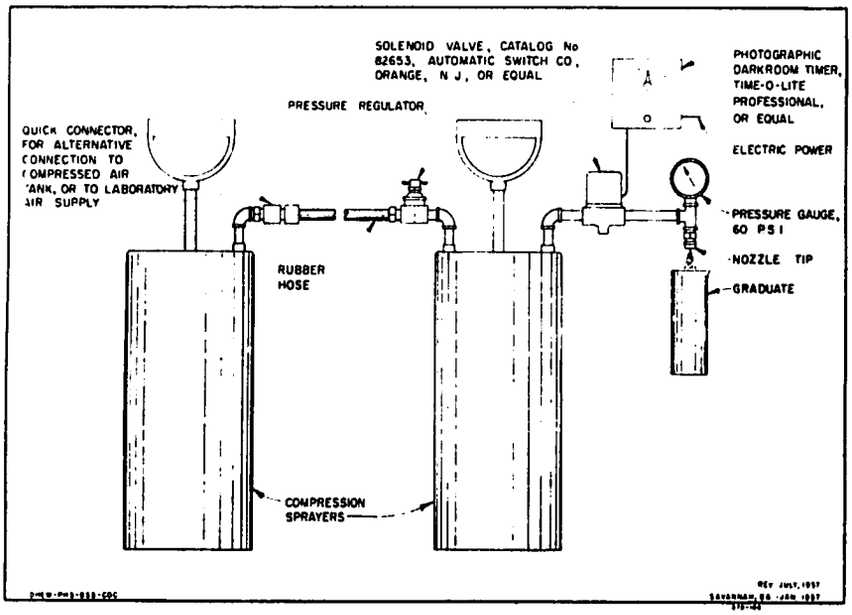
Proposed Method [1]

The following field procedure for predicting the effect of nozzle erosion on the discharge rates of nozzles has been developed:

(1) Determine the average discharge pressure of the nozzle. Spraying operations on most programmes have been standardized to the point where the average discharge pressure for spraying the contents of a compression sprayer is already known, or can be determined or closely estimated.

(2) Determine the initial discharge rate of the new nozzle. This may be accomplished by the device shown in Fig. 1, or by any other similar device that will give accurate and reproducible results.[2] The discharge pressure in this determination must be the same as was established in (1) above.

FIG. 1. CALIBRATION EQUIPMENT FOR NOZZLE TIPS



(3) Make a second determination of the discharge rate of the nozzle. This is accomplished in the same manner as in (2) above, but after the nozzle has discharged a known volume of spray liquid under normal usage.

[1] The method presented is primarily for use with the "Teejet" nozzles manufactured by the Spraying Systems Co., Bellwood, Ill., USA. Specifically, it may be used for water-wettable DDT sprays discharging through brass, stainless steel, and hardened stainless steel nozzles and for water-wettable dieldrin sprays discharging through stainless steel nozzles of this type and manufacturer. Although some data for nozzles of types other than the above were included in the development of this method, it is believed that the method should not be generally applied to other types of nozzles unless experimental studies so indicate.

[2] Clear water is used in this device. This measurement, as well as all subsequent discharge measurements, is made with clear water after the nozzle orifice has first been thoroughly cleaned.

FIG. 2. COMPARISON OF DATA FROM TWO STUDIES WHERE EFFECTS OF EROSION ON STAINLESS STEEL NOZZLES (TYPE 8002) WERE MEASURED IN TERMS OF INCREASE IN DISCHARGE RATE OVER INITIAL DISCHARGE RATE COMPARED WITH QUANTITY OF MATERIAL SPRAYED

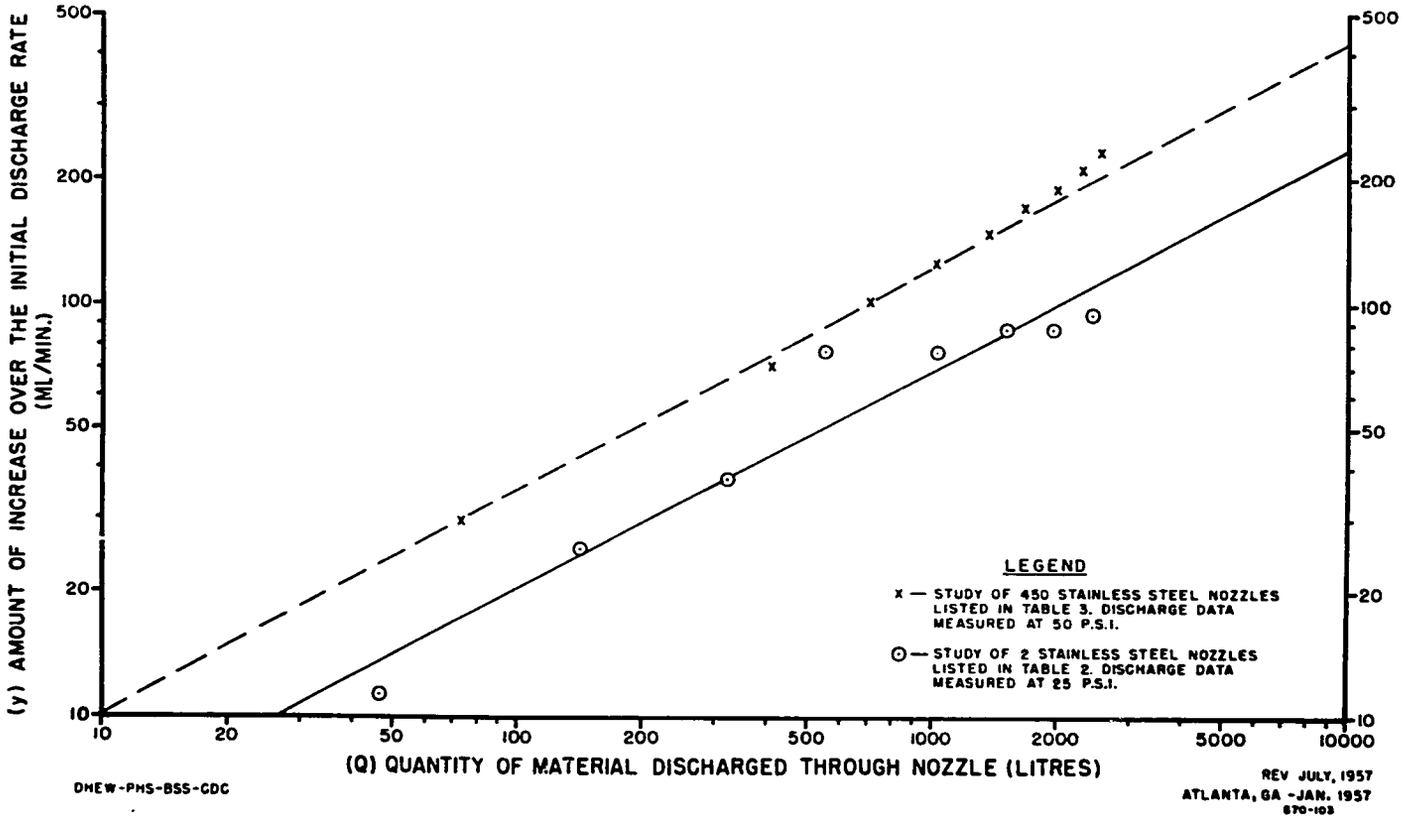
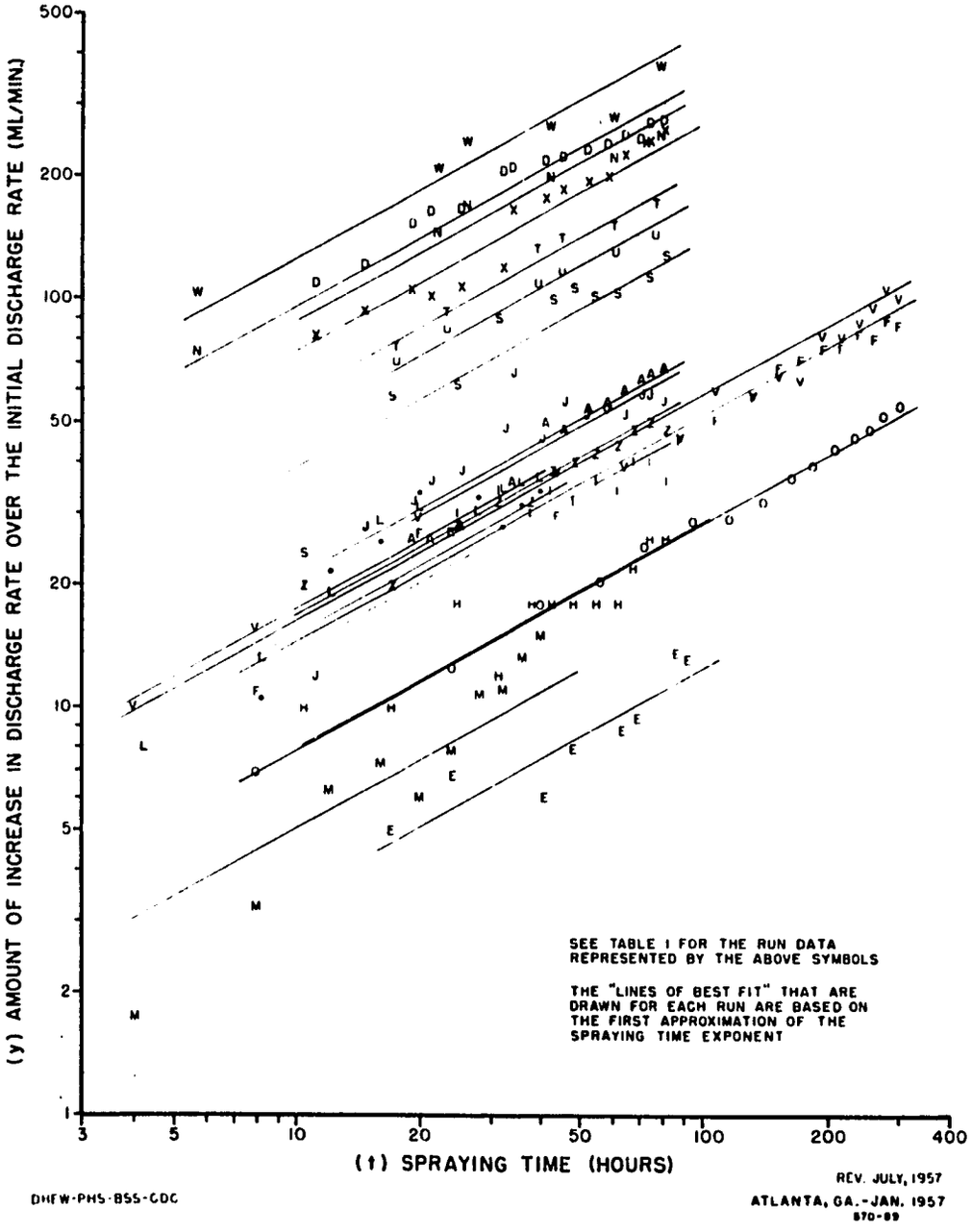


FIG. 3. INCREASE IN DISCHARGE RATE WITH SPRAYING TIME FOR NOZZLES TESTED IN ACCORDANCE WITH DATA LISTED IN TABLE 1

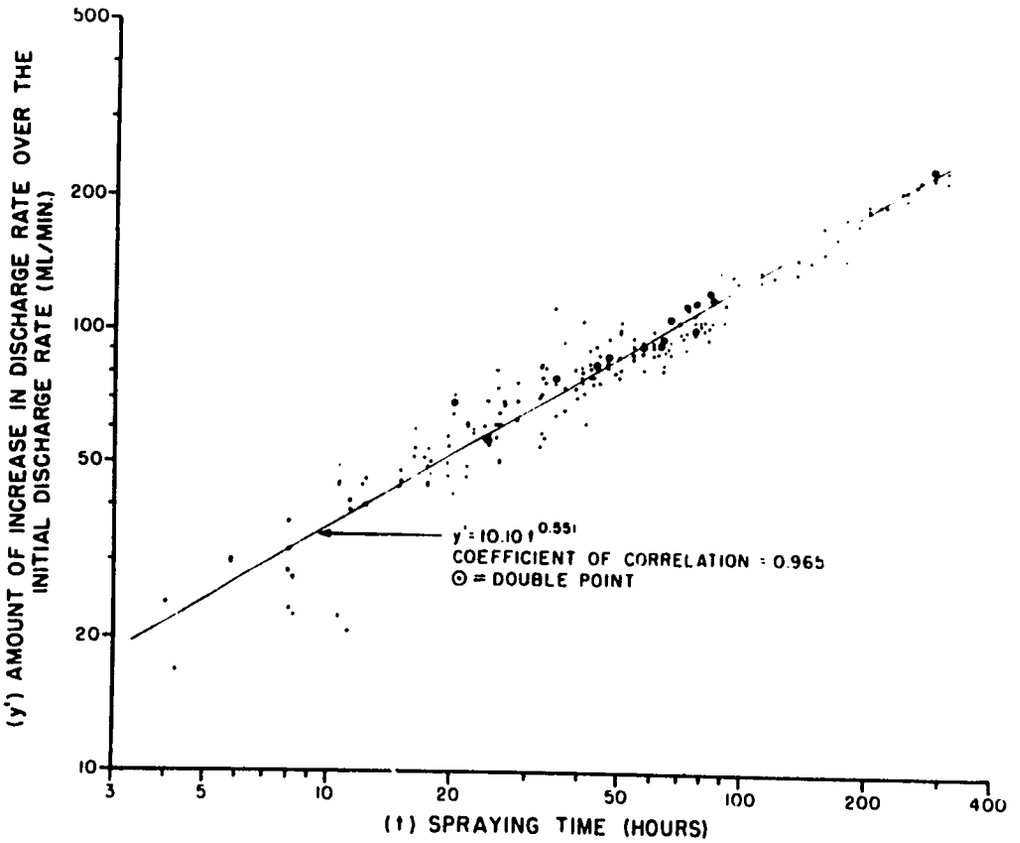


(The volume of spray material discharged between determinations should be at least 150 litres.)

(4) Compute the difference between the two discharge rates as determined in (2) and (3) above. Using this value and the known volume of material sprayed between the two discharge determinations, locate a point on Fig. 2 by plotting these two values as co-ordinates.

(5) Through the point located in (4) above, draw a line parallel to the other lines on Fig. 2. This line then represents the change in discharge rate for any quantity of material sprayed by the nozzle, provided the nozzle continues to be used under the same conditions which existed between the first two discharge determinations (i.e., same average discharge pressure and type and concentration of insecticide).

FIG. 4. SCATTER DIAGRAM FOR INCREASE IN DISCHARGE RATE WITH SPRAYING TIME *



* Increases in discharge rate data for the individual runs shown in Fig. 3 are modified by being multiplied by the ratio of the average nozzle erosion coefficient for all the runs to the nozzle erosion coefficient for the individual run (i.e., $y' = (c/c)y$).

TABLE 1. NOZZLE DATA AND TEST CONDITIONS FOR EROSION TESTING OF 30 NOZZLES WHEN TEST SUSPENSIONS WERE RECIRCULATED

Run No.	Nozzle			Spray pattern	Discharge pressure (p.s.i.)	Test suspension, concentration and material	Time between suspension changes (hours)	Test time (hours)	Symbol used to plot observed data in Fig. 3
	type *	number tested	material **						
1	8002	1	SS	Fan	40	5 % from 50 % water-wettable DDT	2 to 7	81	A
1	8002	1	SS	Fan	40	,,	3 to 7	82	Z
1	F45080	1	SS	Fan	40	,,	2 to 7	81	J
1	8002	1	HSS	Fan	40	,,	3 to 7	82	H
1	6502	1	HSS	Fan	40	,,	3 to 7	82	I
1	Hudson	1	Unknown	Cone	40	,,	3 to 7	82	S
1	8002	1	Brass	Fan	40	,,	2 to 7	81	D
1	F45080	1	Brass	Fan	40	,,	2 to 7	81	X
2	8002	2	Brass	Fan	10	,,	6 to 17	77	U
2	8004	2	Brass	Fan	10	,,	6 to 17	77	T
2	8002	2	Brass	Fan	20	,,	6 to 17	79	N
2	8004	2	Brass	Fan	20	,,	6 to 17	79	W
3	8002	2	SS	Fan	25	1.3 % from 50 % water-wettable dieldrin	4	40	M
3	8002	2	SS	Fan	25	5 % from 75 % water-wettable DDT	4	40	L
3	8002	2	HSS	Fan	25	,,	4	40	.
4	8002	2	SS	Fan	25	1.3 % from 50 % water-wettable dieldrin	Not changed	92	E
5	8002	2	SS	Fan	25	,,	4	301	O
6	8002	2	SS	Fan	25	5 % from 75 % water-wettable DDT	4	300	V
6	8002	2	HSS	Fan	25	,,	4	300	F

* 6502, 8002 and 8004 nozzles furnished by Spraying Systems Co., Bellwood, Ill., USA. F45080 nozzles furnished by Bete Fog Nozzle Inc., Greenfield, Mass. USA. Hudson nozzle furnished by H. D. Hudson Mfg. Co., Chicago, Ill., USA.
** SS = 18-8 stainless steel. HSS = Hardened stainless steel.

Development of the Method

The method for predicting increase in nozzle discharge was based on discharge rates for three groups of nozzles investigated for erosion resistance to water-wettable insecticides. The test conditions for the first two groups of nozzles are given in Tables 1 and 2. The data for the third group of nozzles (Table 3) are from an unpublished report by P. S. Echaves on the effect of erosion on nozzles used in the Taiwan Malaria Control Programme.

TABLE 2. NOZZLE DATA AND TEST CONDITIONS FOR EROSION TESTING OF 4 NOZZLES WHEN TEST SUSPENSIONS WERE DISCHARGED TO WASTE

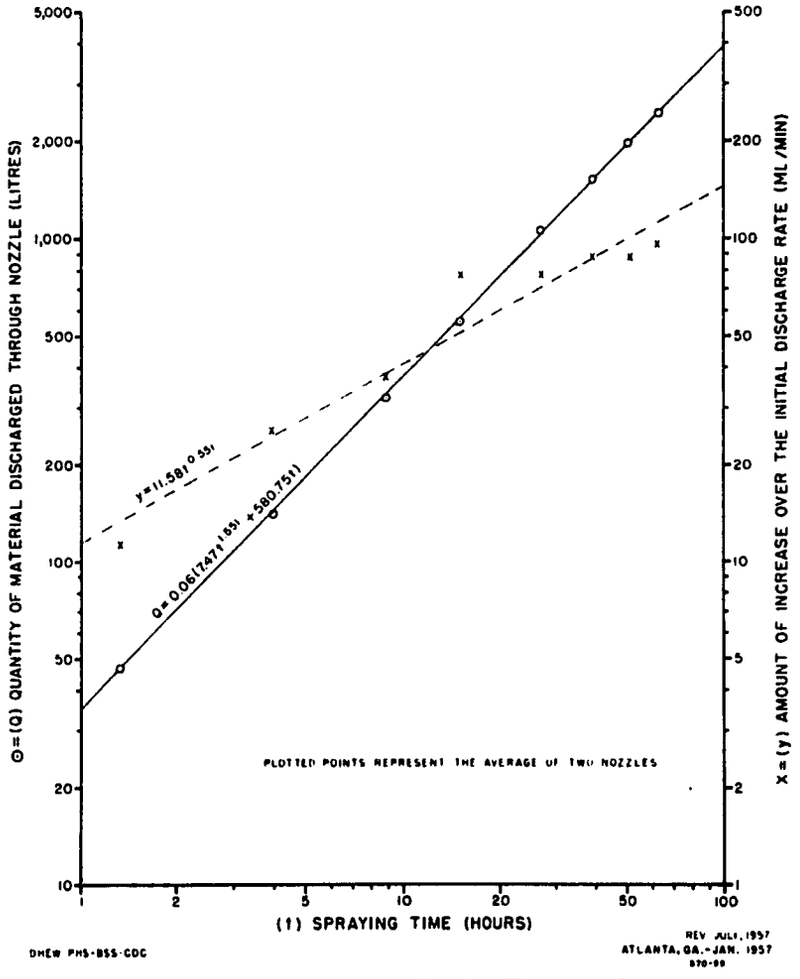
Run No.	Type of nozzle *	Number of nozzles tested	Nozzle material**	Spray pattern	Discharge pressure (p.s.i.)	Test suspension, concentration and material	Time between suspension changes	Test time (hours)
7	8002	2	SS	Fan	25	5% from 75% water-wettable DDT	0	63
7	8002	2	HSS	Fan	25	"	0	63

* 8002 nozzles furnished by Spraying Systems Co., Bellwood, Ill., USA.
** SS = 18-8 Stainless steel. HSS = Hardened stainless steel.

The increase in discharge rate with spraying time was plotted logarithmically in Fig. 3 for individual runs listed in Table 1. By the method of least squares, the slope of the line of best fit was determined for each run. These slopes were weighted according to the number of nozzles tested and the number of discharge determinations made in each run. A weighted average slope was calculated for all the runs. Using the value of this slope as a first approximation of the spraying time exponent, the nozzle erosion coefficient and the equation of the line of best fit were calculated for each run. The lines representing these equations are shown in Fig. 3.

The scatter diagram (Fig. 4) is the average of all the plotted data of Fig. 3. The points on the diagram were determined by multiplying the observed discharge data for each run by the ratio of the average nozzle erosion coefficient to the nozzle erosion coefficient for the particular run and then plotting these data against the corresponding spraying time. By the method of least squares, a value of 0.551 for the slope of the line that best fit all the points was found. A linear relationship between the plotted points was established by the determination of a 0.965 coefficient of correlation. Based on the method used to construct this diagram and the relationships found between the plotted data, it was assumed for this first group of nozzles that the spraying time exponent was independent of the nozzle erosion conditions

FIG. 5. INCREASE IN DISCHARGE RATE OVER INITIAL DISCHARGE RATE AND ACCUMULATIVE VOLUME OF MATERIAL SPRAYED WHEN STAINLESS STEEL NOZZLES (TYPE 8002) WERE ERODED BY 5% SUSPENSIONS OF 75% WATER-WETTABLE DDT *

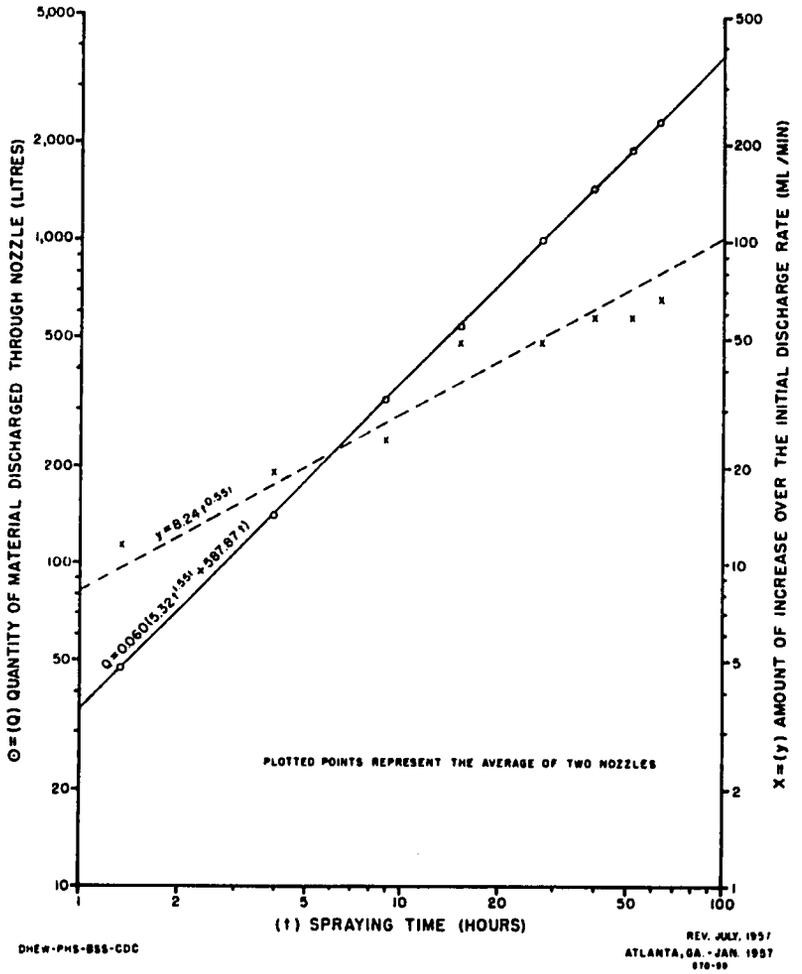


* Spray material was discharged to waste at 25 p.s.i. (1.75 atm.) nozzle pressure.

and that the nozzle erosion coefficients were directly related to the nozzle erosion conditions.

The observed data showing the increase in discharge rate with spraying time and quantity of material sprayed were plotted in Fig. 5 and 6 for the two nozzles listed in Table 2. Also plotted in these figures were the corresponding calculated lines that best represented the plotted information. The equations for these lines were determined from the same value of the spraying time exponent that was found for the nozzles in Table 1. A comparison of

FIG. 6. INCREASE IN DISCHARGE RATE OVER INITIAL DISCHARGE RATE AND ACCUMULATIVE VOLUME OF MATERIAL SPRAYED WHEN HARDENED STAINLESS NOZZLES (TYPE 8002) WERE ERODED BY 5% SUSPENSIONS OF 75% WATER-WETTABLE DDT*



* Spray material was discharged to waste at 25 p.s.i. (1.75 atm.) nozzle pressure.

the observed and calculated data indicated that the assumptions stated in the previous paragraph were also valid for this second group of nozzles.

The nozzle discharge data which were plotted in Fig. 2 are those tabulated in Table 3, together with the observed data for one set of nozzles listed in Table 2. For Fig. 2, discharge rate readings were plotted against the quantity of material sprayed since spraying time was not included with the data in Table 3. As in the previous figures, the calculated lines best representing the observed information were also plotted. Again, a com-

TABLE 3. FIELD DATA SHOWING EFFECTS OF EROSION ON INCREASE IN DISCHARGE RATE ON 450 STAINLESS STEEL NOZZLES (TYPE 8002) USED IN TAIWAN MALARIA CONTROL PROGRAMME *

Average discharge rate ** (ml/min.)	Quantity of material passing through nozzle (litres)	Amount of increase over initial discharge rate (ml/min.)	Discharge pressure (p.s.i.)	Test suspension, concentration and material	Time between suspension changes
799.83	0	0	Unknown	Unknown	0
829.44	73.14	29.61	,,	,,	0
871.11	412.35	71.28	,,	,,	0
901.80	707.13	101.97	,,	,,	0
925.45	1023.15	125.62	,,	,,	0
948.76	1371.81	148.93	,,	,,	0
970.81	1686.49	170.98	,,	,,	0
989.10	2006.56	189.27	,,	,,	0
1010.58	2306.25	210.75	,,	,,	0
1032.74	2580.18	232.91	,,	,,	0

* Unpublished data from P. S. Echaves
** Discharge rate observations were determined at approximately 50 p.s.i.

parison of the observed and calculated information of this figure substantiates the assumptions made for the first group of nozzles.

The results obtained indicated that the discharge rate equation for all nozzles tested may be expressed as: $y = ct^{1/m}$, where y represents the increase in discharge rate in millilitres per minute, c the nozzle erosion coefficient, t the spraying time in hours, and $1/m$ the spraying time exponent. The value of this exponent was found to be 0.551.

The equations for expressing the volume of material discharged in litres are:

$$(a) \qquad Q = \frac{60}{1000}\left[\int y\,dt + \int IDR\,dt\right]$$

$$= 0.06\left[\frac{ct^{1.551}}{1.551} + IDR\,(t)\right]$$

or:

$$(b) \qquad Q = 0.06\left[\frac{c}{1.551}\,(y/c)^{2.815} + IDR\,(y/c)^{1.815}\right]^{*}$$

where IDR equals the initial discharge rate of nozzle in millilitres per minute.

* The relationship between Q and y is not exactly linear, although in practice it can be regarded as linear.

The nozzles in Table 3 had a greater increase in discharge rate than those in Table 2 because the discharge rates of the former were measured at approximately 50 pounds per square inch (p.s.i.), or about 3.5 atmospheres, whereas the latter were measured at 25 p.s.i. (1.75 atm.). Consequently, the data required for predicting the increase in discharge rates of nozzles must be observed at the same discharge pressure that the nozzles are to be subjected to during field use.

RÉSUMÉ

L'érosion des orifices des buses de pulvérisateurs, sous l'effet du passage de l'insecticide, peut entraîner des pertes économiques sensibles dans les programmes de lutte, par suite du débit excessif d'insecticide. Les facteurs responsables de cette érosion peuvent varier beaucoup. Les auteurs décrivent une méthode permettant d'évaluer l'effet de l'érosion sur le débit des buses, d'après deux mesures seulement: le débit de la buse neuve et celui de la buse après pulvérisation d'au moins 150 litres (dans les mêmes conditions de pression, avec le même type et la même concentration d'insecticide). Des formules permettent de calculer la corrosion probable et le débit qui en résulte, pour des buses en laiton, en acier inoxydable, pour des poudres mouillables de DDT et de dieldrine.

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